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Modeling of an excogitative pumping process for high temperature fluid

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Abstract

High temperature fluids find significant applications in many of the industries. Use of normal pumps for high temperature fluids leads to complications such as damage of pumps, leakage of seals and stalled drives. The pumps available in market are not suited for hot fluid transportation as it results in cavitation. In order to tackle the aforementioned problem a suitable pneumatic pump had been designed and fabricated. This pump uses compressed air to pump the hot fluid, with lesser moving parts. It is more compatible with hot fluids, inexpensive with low maintenance and light weight. The compressed air is inducted into the regulating section where its direction, rate of flow and pressure are regulated. The regulated air is then sent to pumping section consisting of dual chambers. The principle behind this excogitative type of pump is that, the pressure energy of compressed air is converted into equivalent static head (potential energy) of the fluid to be pumped. The hydraulic energy of compressed air is exchanged into hydraulic energy of the fluid to be pumped. Consequently the mutual exchange of energy from air to liquid takes place.

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Keywords: Static head, Mutual exchange, Cavitation, Dual Chambers, Compressed air

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1. Introduction

The proposed pneumatic pump model is to be used for transportation of high temperature fluid. The pump has a regulating section and a pumping section. The compressed air first enters into the regulating section where its pressure, direction and rate of flow are regulated. The regulated air is then sent to the pumping section which has dual chambers. The air is alternatively sent to the dual chambers to produce a continuous smooth flow. The pump has many advantages such as inexpensiveness, light weight, low maintenance with the only disadvantage it needs positive / flooded suction.

2. Line Diagram

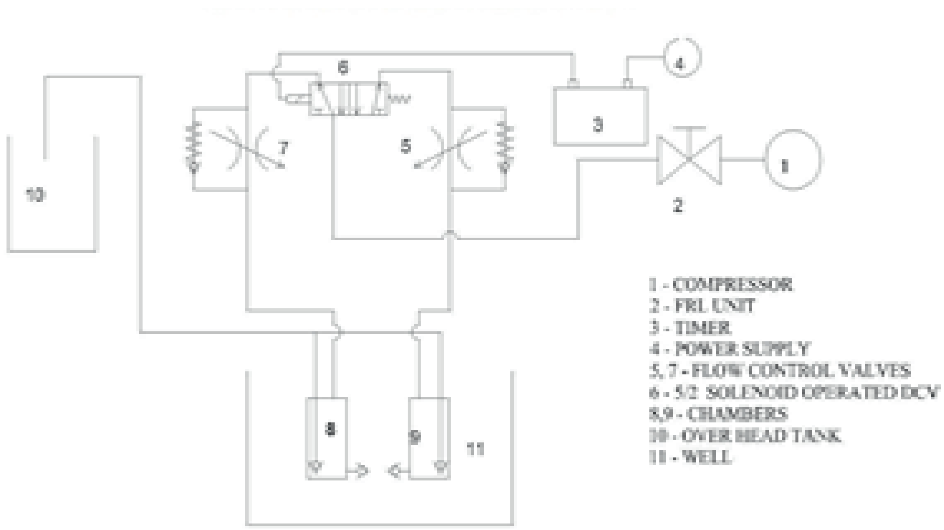

Fig. 1:Line diagram of the setup.

3. Description of the setup

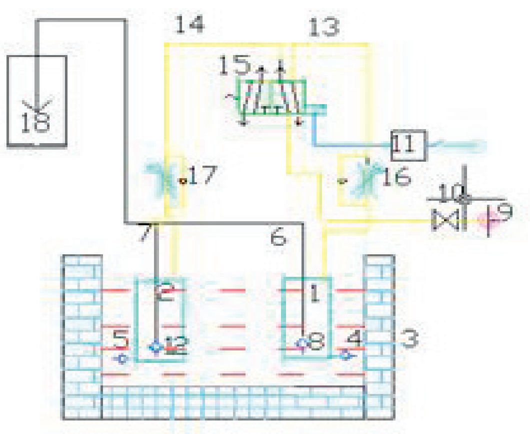

Fig. 2: Description of the setup

1. Chamber-1
2. Chamber-2
3. Well
4. Inlet Valve for Chamber-1
5. Inlet Valve for Chamber-2
6. Discharge Line -1
7. Discharge Line -2
8. Check Valve-1
9. Compressor
10. Air Isolation Valve
11. Power Supply
12. Check Valve-2
13. Air Line to Chamber-2
14. Air Line to Chamber-1
15. 5/2 Solenoid by Spring Return-DCV
16. Flow Control Valve to Chamber -1
17. Flow Control Valve to Chamber -2
18. Over Head Tank

3.1. Directional control valve

¼"BSP port size, 5 Ports, 2 Positions, Solenoid operated spring return DCV is used here.Direction Control valve is used to change the direction of the flow of air by means of the sliding movement of spool rod. It is operated by the solenoid. The forward movement of spool is effected by energizing the solenoid and the retraction is done by the spring. The energizing and de-energizing of solenoid is controlled by a timer circuit. The solenoid is operated at 230 V- 50 Hz. A.C. signals are generated by thetimer circuit.

3.2. Check valve:

Check valve is used to allow unidirectional flow of water. It is fixed at the bottom of the chamber. That is placed inside the tank. The water enters from tank/well to the chamber through the check valve. It is operated by spring action. It will not allow the backflow of water from the chamber to the tank/well. Once the water is discharged, the chamber is again filled with water.

3.3. Flow control valve:

Flow control valve is used to control the amount of air entering into the chamber.Rotation in the clockwise direction decreases airflow while rotation in the opposite direction increases it. The flow is regulated only in one direction. This implies that there is no regulation in the opposite direction, i.e. "Free flow" takes place. The "controlled flow" and "Free flow" directions are marked on the valve body.

3.4. Timer circuit:

Input to timer: 230V, 50 HZ.
Output from timer: 230V A.C.Frequency is varied as per the amount required for the operation of the pump.

Time circuit is used to control the direction. The pump discussed in this paper is designed to operate for 5seconds and remain in OFF state for 5seconds. The ON and OFF timings depend upon various system parameters like static head under which the pump suction is located, size of DC Valve, pipe line / hose size selected, Check valve size etc. During the first half, water is filled in the first chamber while water is delivered from the second chamber and during the next half the water is filled in second chamber while water is delivered from the first chamber. The cycle is continued in order to obtain a constant flow.

4. Construction

It consists of a Compressor, a Direction Control Valve, 2 Flow Control Valves, well/tank, anOverhead tank, a T-Connector, a Check valve, Two Chambers and a Timer circuit.

The two chambers are placed inside a reservoir. Initially the chambers are filled with water. An air compressor is connected to the DCV through an isolation valve. Power supply is given to the solenoid. There are two outlet ports in the DCV. One is connected to the first chamber and the other is connected to the second. Outlets of the chambers are connected to the overhead tank through the T-Connector. Check valves are connected at the bottom of the chambers. Flow control valve is connected between the DCV and the chambers.

There are three ports in the inlet side of the DCV. First and last ports are used for releasing the air from the chamber to ambient. The middle port is for the inlet of air from the compressor.

5. Calculation of delivery height

Delivery height for the given pressure can be calculated by using the formula

$$P = W * H$$

Where,

P = required operating pressure of the pump in N/m^2

W = weight density of the fluid to be handled [water w=9810 N/m^3]

H = height of the fluid to be lifted for single stage compression(maximum pressure is 10 bar)

$$P=W * H$$

$$1 \text{ bar} = 10^5 \text{ N/M}^2$$

$$10^5=9810* H$$

$$H=10^5/ 9810$$

$$H=101.9 \text{ m}$$

6. Calculation of maximum pressure with standby shell

$$\sigma_c = (p*d)/(2*t)$$

Where

σ_c=circumferential stress (or) hoop's stress

p=intensity of internal pressure

d=diameter of the shell

t=thickness of the shell

The stress should be below the yield strength, hence assume

σ_c=10 kgf /mm^2

σ_c=100 N/mm^2

100 = P* B0/10

P=7.69 Mpa=76.9 bar

The design is theoretically proven to be safe.

For designing pressure vessel only circumferential stress is considered.

7. Fabrication process

7.1. Barrel

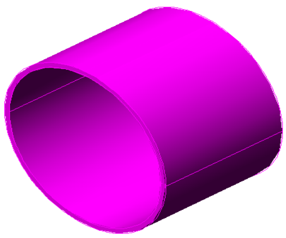

Fig.3: Barrel

Initially the board is cut to required dimension (250 mm, 250 mm, and 100 mm).

7.2. Making of flange

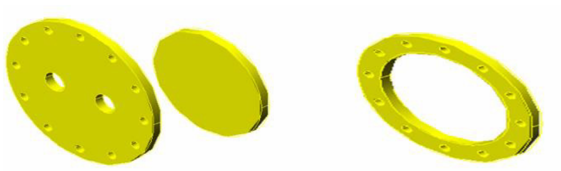

Fig.4: flange

The plates are made to the required dimensions by turning and 12 holes are drilled on solid and hollow plates.

7.3. Assembly of flange and barrel

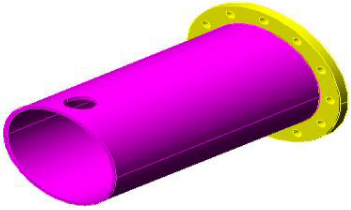

Fig.5: flange and barrel

The ring is welded to the barrel. The solid plates are joined with the aide of bolts and nuts.

7.4. Assembly of chamber

Fig.6: Chamber

After fixing all the components, the 2 (250 mm) cores are joined by a small board (100mm) by means of welding.

8. Working

Initially the two chambers are filled with water. Timer circuit is switched ON. Then the air compressor is switched on. Air is pressurized to the required amount (5 bar) and is supplied. It depends on the height to be lifted. The DCV is kept in its initial position. The inlet is connected to the second chamber and the outlet to the first. The flow control valve controls the air flow to the chambers. When the air enters the chamber, the water is forced out through the outlet to the overhead tank. This will be in operation for 5 sec.

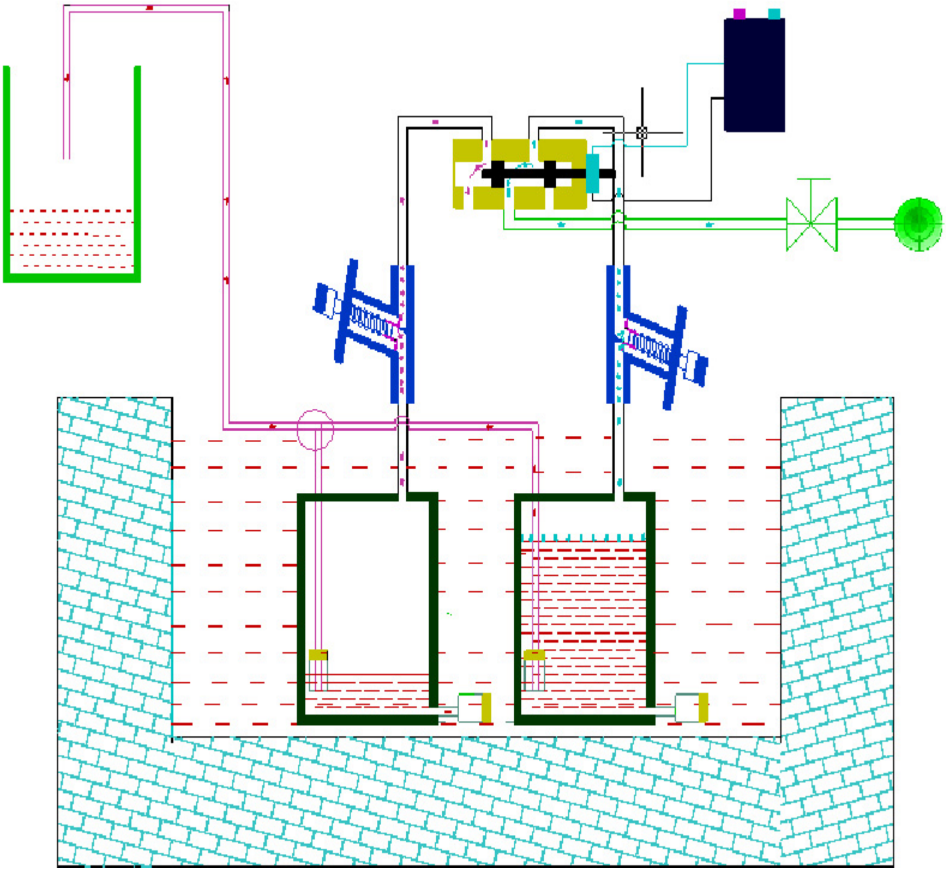

Fig. 7: First cycle operation

Now the DCV is shifted to the next position. The inlet is connected to the second chamber and the outlet is connected to the first. Now the remaining air in the chamber is released to the atmosphere. While air is supplied to the second chamber the first chamber is simultaneously filled with water. Entry of air forces the water inside the chamber to the overhead tank. This will be in operation for the next 5 sec. DCV is shifted to the initial position. Once again the same process is repeated.

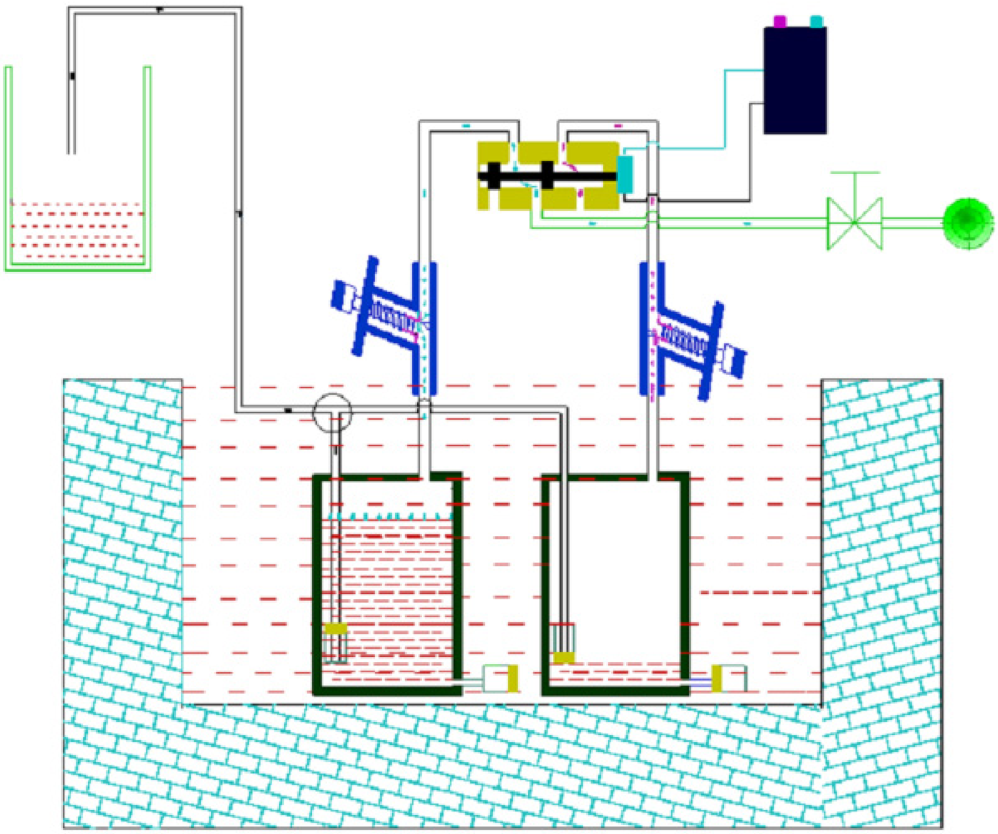

Fig. 8: Second cycle operation

9. Advantages

- It has fewer moving components which move very gently.
- It can be used for mixing 2 ormore fluids in different ratios, which can be applicable in chemical industries.
- This can be used to pump dirty water, chemicals etc.
- Negligible electrical hazard.
- Very simple in construction.
- Easy to maintain.
- Portable and initial cost is very less.

10. Conclusion

This is a new type of pump with many salient features. This hasversatile applications like agriculture, domestic, industrial purposes with little investment. The proposed model can be used in thermal power plant where high temperature fluid is pumped in huge masses.

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